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(71) Applicant *(for all designated States except US)*: CASIO COMPUTER CO., LTD. [JP/JP]; 6-1, Nishi-Shinjuku 2-chome, Shinjuku-ku, Tokyo 160 (JP).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: SUZUKI, Yukio [JP/JP]; 3-16-7-204, Gonokami, Hamura-shi, Tokyo 205 (JP). NAKAMURA, Hideki [JP/JP]; 6-23-5-107, Kawabe-cho, Oume-shi, Tokyo 198 (JP). SUZUKI, Akira [JP/JP]; 5-5-6-201, Mibori-cho, Akishima-shi, Tokyo 196 (JP).

(74) Agents: SUZUYE, Takehiko et al.; Suzuye & Suzuye, 7-2, Kasumigaseki 3-chome, Chiyoda-ku, Tokyo 100 (JP).

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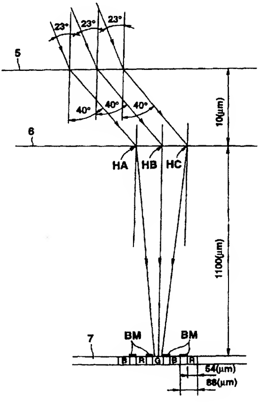
(54) Title: LIQUID CRYSTAL DISPLAY APPARATUS

(57) Abstract

Parallel light, which is emitted from a lamp (1) for generating white light and is reflected by a reflector (2), enters a first holographic optical element (5). The first holographic optical element (5) splits the parallel light into a plurality of color light components of different wavelength bands, and emits the light components. The light components emitted from the first holographic optical element (5) hit a second holographic optical element (6) at different incident angles wavelength by wavelength. The second holographic optical element (6) causes lights of different wavelength bands to be incident to respective pixels of a liquid crystal device (7).



DESCRIPTION

LIQUID CRYSTAL DISPLAY APPARATUS

Technical Field

The present invention relates to a liquid crystal display apparatus, and, more particularly, to a color liquid crystal display apparatus which uses optical means such as holographic optical element.

Background Art

There is a known liquid crystal display (LCD) apparatus which irradiates light from a back light source on a liquid crystal (LC) cell to display a color image. This LCD apparatus uses red (R), green (G) and blue (B) color filters corresponding to the pixels of the LC cell. This LCD apparatus displays a color image as the light from the back light source is colored at the time of passing through the color filters.

When the light from the back light source passes through the color filters in this LCD apparatus, however, the color filters absorb lights of complementary color components. The LCD apparatus therefore has a poor efficiency of using light from the back light source and suffers dark color display.

In view of the above situation, an LCD apparatus has recently been developed which improves the light use efficiency by using a holographic optical element. This LCD apparatus has a holographic optical element provided between the light source and the LC cell. This holographic optical element splits parallel light from the back light source to light components of R, G and B wavelengths. The split lights are condensed on the pixels of the LC cell of the associated colors. Accordingly, the lights of the individual wavelengths enter the respective pixels of the LC cell wastelessly.

Each of multiple diffraction gratings of the holographic optical element of this LCD apparatus diffracts light of any one of wavelengths of the parallel light

incident at a certain angle of incidence (incident angle). Since there are different diffraction angles for different wavelengths of light, light of each wavelength enters the associated pixel of the LC cell.

The diffraction angle and diffraction efficiency of this holographic optical element for light of each wavelength are determined by the incident angle of light to the holographic optical element. Therefore, the intensity of light incident to each pixel of the LC cell is not fixed but varies wavelength by wavelength. A generally used holographic optical element has the highest diffraction efficiency for the G wavelength component among the R, G and B wavelength components. It is therefore difficult to acquire a good color characteristic with balanced R, G and B colors.

Disclosure of Invention

Accordingly, it is an object of the present invention to provide an LCD apparatus which can acquire a good color characteristic with balanced R, G and B colors.

To achieve the above object, an LCD apparatus according to one aspect of this invention comprises:

a light source (1, 2) for supplying a substantially parallel light flux;

an LC device (7) having multiple pixels;

a first holographic optical element (5, 15) for splitting the substantially parallel light flux from the light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting the split light fluxes in different directions respectively; and

a second holographic optical element (6, 16) for guiding the plurality of light fluxes of different wavelength bands emitted from the first holographic optical element (5, 15) to predetermined pixels of the LC device (7) wavelength band by wavelength band.

A plurality of light fluxes of different wavelength bands, split by the first holographic optical element, hit

the second holographic optical element at different incident angles. Therefore, the second holographic optical element can make the intensities of light components incident to the respective pixels of the LC cell substantially the same for any wavelength band.

Accordingly, this LCD apparatus can acquire an excellent color characteristic with balanced R, G and B colors.

An LCD apparatus according to another aspect of this invention comprises:

a light source (1, 2) for supplying a substantially parallel light flux;

an LC device (7) having multiple pixels;

a prism (20, 25) for splitting the substantially parallel light flux from the light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting the split light fluxes in different directions respectively; and

a holographic optical element (21, 26) for guiding the plurality of light fluxes of different wavelength bands emitted from the prism (20, 25) to predetermined pixels of the LC device (7) wavelength band by wavelength band.

A plurality of light fluxes of different wavelength bands, split by the prism, hit the holographic optical element at different incident angles. Therefore, the holographic optical element can make the intensities of light components incident to the respective pixels of the LC cell substantially the same for any wavelength band.

Accordingly, this LCD apparatus can acquire an excellent color characteristic with balanced R, G and B colors.

An LCD apparatus according to a further aspect of this invention comprises:

a light source (1, 2) for supplying a substantially parallel light flux;

an LC device (7) having multiple pixels;

a holographic optical element (51) for splitting the substantially parallel light flux from the light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting the split light fluxes in different directions respectively; and

a lens (50) for guiding the plurality of light fluxes of different wavelength bands emitted from the holographic optical element (51) to predetermined pixels of the LC device (7) wavelength band by wavelength band.

A plurality of light fluxes of different wavelength bands, split by the holographic optical element, enters the lens at different incident angles. Therefore, the lens can make the intensities of light components incident to the respective pixels of the LC cell substantially the same for any wavelength band.

Accordingly, this LCD apparatus can acquire an excellent color characteristic with balanced R, G and B colors.

In other words, an LCD apparatus according to this invention comprises:

a light source (1, 2) for supplying a substantially parallel light flux;

an LC device (7) having multiple pixels;

first optical means (5, 15; 20, 25; 51) for splitting the substantially parallel light flux from the light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting the split light fluxes in different directions respectively; and

second optical means (6, 16; 21, 26; 50) for guiding the plurality of light fluxes of different wavelength bands emitted from the first optical means (5, 15; 20, 25; 51) to predetermined pixels of the LC device (7) wavelength band by wavelength band.

Brief Description of Drawings

Fig. 1 is a cross-sectional view illustrating the structure of an LC projector according to the first

embodiment of this invention;

Fig. 2 is a diagram showing a light path for a light of a green (G) wavelength component in the LC projector in Fig. 1;

Fig. 3 is a diagram showing a light path for a light of a red (R) wavelength component in the LC projector in Fig. 1;

Fig. 4 is a diagram showing a light path for a light of a blue (B) wavelength component in the LC projector in Fig. 1;

Fig. 5 is a graph depicting the diffraction efficiency of a second holographic optical element of the LC projector in Fig. 1;

Fig. 6 is a diagram showing a first modification of the LC projector according to the first embodiment of this invention;

Fig. 7 is a diagram showing a second modification of the LC projector according to the first embodiment of this invention;

Fig. 8 is a cross-sectional view illustrating the structure of an LC projector according to the second embodiment of this invention;

Fig. 9 is a diagram showing a first modification of the LC projector according to the second embodiment of this invention;

Fig. 10 is a diagram showing a second modification of the LC projector according to the second embodiment of this invention;

Fig. 11 is a cross-sectional view illustrating the structure of an LC projector according to the third embodiment of this invention;

Fig. 12 is a diagram showing a light path for a light of a green (G) wavelength component in the LC projector in Fig. 11;

Fig. 13 is a diagram showing a light path for a light of a red (R) wavelength component in the LC projector in

Fig. 11;

Fig. 14 is a diagram showing a light path for a light of a blue (B) wavelength component in the LC projector in Fig. 11;

Fig. 15 is a cross-sectional view illustrating the structure of an LC projector according to the fourth embodiment of this invention; and

Fig. 16 is a cross-sectional view illustrating the structure of an LC projector according to the fifth embodiment of this invention.

Fig. 17 is a diagram showing a light path from a lamp to pixels of an LC cell of Fig. 16.

Fig. 18 is a diagram showing shapes of microlenses associated with unit pixels.

Fig. 19 is a diagram showing other shapes of microlenses associated with unit pixels.

Best Modes for Carrying Out the Invention

First Embodiment

Fig. 1 illustrates the structure of an LCD projector according to the first embodiment of this invention.

In this LC projector, a lamp 1 which generates white light is located at the focus point of a reflector 2 having a parabolic surface. The reflector 2 reflects the light from the lamp 1 to be parallel to an optical axis 3. A polarization plate 4 which passes light of a specific polarized light component is provided perpendicular to the optical axis 3 on the light reflecting side of the reflector 2. (This polarization plate 4 will hereinafter be called "incident-side polarization plate.") Arranged on the light outgoing side of the incident-side polarization plate 4 is a first holographic optical element 5 inclined to the optical axis 3 by a predetermined angle. Accordingly, a parallel light of a specific polarized light component which has passed the incident-side polarization plate 4 enters the first holographic optical element 5 at a predetermined incident angle. On the light outgoing side

of the first holographic optical element 5, a second holographic optical element 6 is provided parallel to the first holographic optical element 5. On the light outgoing side of the second holographic optical element 6, an LC cell 7 is provided parallel to the second holographic optical element 6. On the light outgoing side of the LC

cell 7, a polarization plate 8 (hereinafter called "outgoing-side polarization plate") which passes a specific polarized light component is provided parallel to the LC cell 7. A projection lens 9 for projecting an image of light which has passed the outgoing-side polarization plate 8 is located on the light going side of the outgoing-side polarization plate 8.

The LC cell 7 has a liquid crystal sealed between a pair of transparent substrates on which electrodes are formed in a dot matrix form and multiple pixels are arranged in a dot matrix form. A black matrix BM for preventing light leakage is provided between the pixels on the substrate to which light is incident. The LC cell 7 has unit pixels each consisting of a set of three color (R, G and B) pixels. One side of each pixel has a size of 54 μm and the pitch between the pixels is 88 μm. This LC cell 7 is provided with color filters for R, G and B. The LC cell 7 may however have no color filters.

The incident-side polarization plate 4 passes a specific polarized light component (e.g., either linearly polarized S light component or P light component) included in the parallel light which has been emitted from the lamp 1 and has been reflected by the reflector 2. The outgoing-side polarization plate 8 passes a specific polarized light component in the light outgoing from the LC cell 7.

The first holographic optical element 5 diffracts light of any wavelength with each diffraction grating. The diffraction angle of the light diffracted by the first holographic optical element 5 varies in accordance with the wavelength. The diffraction gratings of the first holographic optical element 5 are formed at a uniform pitch d (= 2.182 nm).

The first holographic optical element 5 is inclined to the optical axis 3 of the lamp 1 by 23° in order to cause lights of three wavelength components of R, G and B (hereafter called as "light of the R wavelength component,"

"light of the G wavelength component" and "light of the B wavelength component") incident to the second holographic optical element 6 at specific incident angles respectively. Accordingly, the incident angle of light to the first holographic optical element 5 becomes 23°. The first holographic optical element 5 diffracts the lights incident at an incident angle of 23° to emit the resultant lights at angles different wavelength by wavelength. The light of the R wavelength component (λ = 640 nm) comes out of the first holographic optical element 5 at an angle of 43°. The light of the G wavelength component (λ = 550 nm) comes out of the first holographic optical element 5 at an angle of 40°. The light of the B wavelength component (λ = 460 nm) comes out of the first holographic optical element 5 at an angle of 37°.

The second holographic optical element 6 diffracts light of any wavelength. The diffraction angle of the light diffracted by the second holographic optical element 6 varies in accordance with the wavelength. The second holographic optical element 6 causes the lights from the first holographic optical element 5, which are incident at specific incident angles for the respective wavelength components, to enter the respective pixels of the LC cell 7 corresponding to the individual colors. As shown in Figs. 2 to 4, the second holographic optical element 6 has unit holographic optical elements arranged in association with unit pixels each consisting of a set of three color (R, G and B) pixels of the LC cell 7. Those unit holographic optical elements have the maximum diffraction efficiency for the R wavelength at a point HA shown in Figs. 2 to 4, the maximum diffraction efficiency for the G wavelength at a point HB shown in Figs. 2 to 4 and the maximum diffraction efficiency for the B wavelength at a point HC shown in Figs. 2 to 4. Therefore, the pitch d_A of the diffraction grating at the point HA is set to 1.006 nm, the pitch d_B of the diffraction grating at the point HB is set

to 0.848 nm and the pitch d_c of the diffraction grating at the point HC is set to 0.733 nm. As shown in Fig. 5, the second holographic optical element 6 has such a characteristic that the diffraction efficiency of light of the G wavelength component is high when lights of individual wavelength components are incident at an incident angle of 40°, the diffraction efficiency of light of the R wavelength component is high when lights of individual wavelength components are incident at an incident angle of 43° and the diffraction efficiency of light of the B wavelength component is high when lights of individual wavelength components are incident at an incident angle of 37°.

The second holographic optical element 6 is arranged at an interval of approximately 10 μm with respect to the first holographic optical element 5. The second holographic optical element 6 has an interval of approximately 1100 μm with respect to the surface of the LC cell 7 to which light is incident.

The operation of this LC projector will now be described.

In this LC projector, as shown in Fig. 1, the light from the lamp 1 is reflected by the reflector 2 to become parallel to the optical axis 3. This parallel light comes perpendicularly incident to the incident-side polarization plate 4, which selectively passes the light of a specific polarized light component. The light of the specific polarized light component selected by the incident-side polarization plate 4 enters the first holographic optical element 5 at an incident angle of 23°. The lights of the R, G and B wavelength components incident to the first holographic optical element 5 are diffracted at different diffraction angles by the first holographic optical element 5 and respectively go out thereof at different outgoing angles, as shown in Figs. 2 to 4. The lights which have left the first holographic optical element 5 enter the

second holographic optical element 6 at the optimal incident angles for the respective wavelength components. The lights of the individual wavelength components incident to the second holographic optical element 6 are condensed to the associated pixels of the LC cell 7 corresponding to the respective colors.

The above will be discussed specifically for each of the R, G and B wavelength components.

As shown in Fig. 2, the light of the G wavelength component incident to the first holographic optical element 5 at an incident angle of 23° is diffracted and goes out of the first holographic optical element 5 at an outgoing angle of 40°. The light having left the first holographic optical element 5 enters the second holographic optical element 6 at an incident angle of 40°. The light incident to the point HB of the second holographic optical element 6 leaves the second holographic optical element 6 substantially perpendicularly and hits the associated pixel for G of the LC cell 7. The light incident to the point HA of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for G of the LC cell 7. The light incident to the point HC of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for G of the LC cell 7.

As shown in Fig. 3, the light of the R wavelength component incident to the first holographic optical element 5 at an incident angle of 23° is diffracted and goes out of the first holographic optical element 5 at an outgoing angle of 43°. The light having left the first holographic optical element 5 enters the second holographic optical element 6 at an incident angle of 43°. The light incident to the point HA of the second holographic optical element 6 leaves the second holographic optical element 6 substantially perpendicularly and hits the associated pixel

for R of the LC cell 7. The light incident to the point HB of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for R of the LC cell 7. The light incident to the point HC of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for R of the LC cell 7.

As shown in Fig. 4, the light of the B wavelength component incident to the first holographic optical element 5 at an incident angle of 23° is diffracted and goes out of the first holographic optical element 5 at an outgoing angle of 37°. The light having left the first holographic optical element 5 enters the second holographic optical element 6 at an incident angle of 37°. The light incident to the point HC of the second holographic optical element 6 leaves the second holographic optical element 6 substantially perpendicularly and hits the associated pixel for B of the LC cell 7. The light incident to the point HB of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for B of the LC cell 7. The light incident to the point HA of the second holographic optical element 6 leaves the second holographic optical element 6 at a predetermined outgoing angle and hits the associated pixel for B of the LC cell 7.

According to this LC projector, as described above, the parallel light emitted from the lamp 1 and reflected by the reflector 2 is diffracted at different diffraction angles wavelength by wavelength by the first holographic optical element 5. That is, the outgoing lights of the individual wavelength components from the first holographic optical element 5 enter the second holographic optical element 6 at their optimal incident angles. It is therefore possible to improve the diffraction efficiency of light of each wavelength component by the second

holographic optical element 6. That is, the second holographic optical element 6 can efficiently condense lights of the individual wavelength components onto the associated pixels of the LC cell 7 for corresponding colors. The lights of the individual wavelength components which have passed the LC cell 7 and the outgoing-side polarization plate 8 are projected as an image by the projection lens 9. As a result, a clear and bright projected image can be acquired.

In the above description, light paths for only the R wavelength component (λ = 640 nm), the G wavelength component (λ = 550 nm) and the B wavelength component (λ = 460 nm) have been discussed. The wavelengths of the lights emitted from the lamp 1 are not limited to those three.

For example, light of a wavelength component lying between the R and G wavelength components goes out the first holographic optical element 5 at an outgoing angle of 40° to 43°. The outgoing light from the first holographic optical element 5 is diffracted by the second holographic optical element 6. The outgoing light from the second holographic optical element 6 enters one of a pixel for R of the LC cell 7, the black matrix BM and a pixel for G of the LC cell 7 in accordance with the wavelength. In other words, light of a given wavelength band around the R wavelength component enters a pixel for R of the LC cell 7, and light of a given wavelength band around the G wavelength component enters a pixel for G of the LC cell 7.

Yellow light, which belongs to neither band, is absorbed by the black matrix BM. Even though the LC cell 7 has no color filters, therefore, the color of light leaving the LC cell 7 does not become unclear.

Although the above-described LC projector has the first and second holographic optical elements 5 and 6 arranged side by side, the arrangement is not limited to this particular type but may take a form as shown in Fig. 6 or Fig. 7.

In the first modification illustrated in Fig. 6, a transparent plate 10 of glass or the like is arranged on the light outgoing side of the incident-side polarization plate 4, inclined at a predetermined angle (23°) with respect to the optical axis 3. The first holographic optical element 5 is provided on the light-incident surface of this transparent plate 10 and the second holographic optical element 6 is provided on the light-outgoing surface of the transparent plate 10.

In the second modification illustrated in Fig. 7, a transparent plate 10 of glass or the like is arranged on the light outgoing side of the incident-side polarization plate 4, inclined at a predetermined angle (23°) with respect to the optical axis 3. The first holographic optical element 5 is provided on the light-outgoing surface of this transparent plate 10 and the second holographic optical element 6 is provided on the light-outgoing surface of the first holographic optical element 5.

The LC projectors according to the first and second modifications have quite the same functions and advantages of the LC projector of the first embodiment.

Second Embodiment

Fig. 8 is a cross-sectional view illustrating the structure of an LCD projector according to the second embodiment of this invention. To avoid the redundant description, like or same reference numerals are given to those components of this embodiment which are the same as the corresponding components of the first embodiment.

The incident-side polarization plate 4 is provided perpendicular to the optical axis 3 on the light reflecting side of the reflector 2, which reflects the light from the lamp 1 to be parallel to the optical axis 3. Arranged on the light outgoing side of the incident-side polarization plate 4 is a first holographic optical element 15 as an optical element inclined perpendicular to the optical axis 3. Accordingly, a parallel light of a specific polarized

light component which has passed the incident-side polarization plate 4 perpendicularly enters the first holographic optical element 15. On the light outgoing side of the first holographic optical element 15, a second holographic optical element 16 is provided parallel to the first holographic optical element 15. On the light outgoing side of the second holographic optical element 16, the LC cell 7, the outgoing-side polarization plate 8 and the projection lens 9 are arranged perpendicular to the optical axis 3 in the named order.

The first holographic optical element 15 diffracts light of any wavelength with each diffraction grating. The diffraction angle of the light diffracted by the first holographic optical element 15 varies in accordance with the wavelength. The diffraction gratings of the first holographic optical element 15 are formed at a uniform pitch d (= 0.856 nm). The first holographic optical element 15 causes lights of three wavelength components of R, G and B to go out at different angles. The lights of the R, G and B wavelength components enter the second holographic optical element 6 at their specific incident angles. Specifically, the light of the R wavelength component (λ = 640 nm) comes out of the first holographic optical element 15 at an angle of 48.4°. The light of the G wavelength component (λ = 550 nm) comes out of the first holographic optical element 15 at an angle of 40°. The light of the B wavelength component (λ = 460 nm) comes out of the first holographic optical element 15 at an angle of 32.5°.

The second holographic optical element 16 diffracts light of any wavelength. The diffraction angle of the light diffracted by the second holographic optical element 16 varies in accordance with the wavelength. The second holographic optical element 16 causes the lights incident at their specific incident angles to enter the respective pixels of the LC cell 7 for corresponding colors. The

second holographic optical element 16 has unit holographic optical elements arranged in association with unit pixels each consisting of a set of three color (R, G and B) pixels of the LC cell 7. Those unit holographic optical elements have diffraction gratings formed in the same way as those of the first embodiment. In the second holographic optical element 16, the pitch d_A of the diffraction grating at the point HA is set to 3.141 nm, the pitch d_B of the diffraction grating at the point HB is set to 2.182 nm and the pitch d_C of the diffraction grating at the point HC is set to 1.624 nm.

According to this LC projector, as apparent from above, the parallel light emitted from the lamp 1 and reflected by the reflector 2 is diffracted at different diffraction angles wavelength by wavelength by the first holographic optical element 15. That is, the outgoing lights of the individual wavelength components from the first holographic optical element 15 enter the second holographic optical element 16 at their optimal incident angles. It is therefore possible to improve the diffraction efficiency of light of each wavelength component by the second holographic optical element 16. That is, the second holographic optical element 16 can efficiently condense lights of the individual wavelength components onto the associated pixels of the LC cell 7 for corresponding colors. As a result, a clear and bright projected image can be acquired.

Since light is perpendicularly incident to the first holographic optical element 15, the reflection at the first holographic optical element 15 can be minimized if the incident light is an S polarized light component. As light of a specific polarized light component perpendicularly enters the first holographic optical element 15, there is less elliptically polarized light produced by the reflection at the back of the first holographic optical element 15. It is thus possible to effectively and

wastelessly use light incident to the first holographic optical element 15.

Further, the lamp 1, the reflector 2 and the incident-side polarization plate 4 can be arranged in a linear fashion, so that this LC projector can be made more compact than the LC projector of the first embodiment.

Although the above-described LC projector has the first and second holographic optical elements 15 and 16 arranged side by side, the arrangement is not limited to this particular type but may take a form as shown in Fig. 9 or Fig. 10.

In the first modification illustrated in Fig. 9, the transparent plate 10 of glass or the like is arranged perpendicular to the optical axis 3 on the light outgoing side of the incident-side polarization plate 4. The first holographic optical element 15 is provided on the light-incident surface of this transparent plate 10 and the second holographic optical element 16 is provided on the light-outgoing surface of the first holographic optical element 15.

In the second modification illustrated in Fig. 10, the transparent plate 10 is arranged perpendicular to the optical axis 3 on the light outgoing side of the incident-side polarization plate 4. The first holographic optical element 15 is provided on the light-outgoing surface of this transparent plate 10 and the second holographic optical element 16 is provided on the light-outgoing surface of the first holographic optical element 15.

The LC projectors according to the first and second modifications have quite the same functions and advantages of the LC projector of the second embodiment.

In the LC projector according to the second embodiment, light hits the LC cell 7 obliquely as compared with the incident light in the LC projector of the first embodiment. It is therefore better that the projection lens 9 should be arranged as shifted from the position of

the LC cell 7.

Third Embodiment

Fig. 11 is a cross-sectional view illustrating the structure of an LCD projector according to the third embodiment of this invention. To avoid the redundant description, like or same reference numerals are given to those components of this embodiment which are the same as the corresponding components of the first embodiment.

The incident-side polarization plate 4 is provided perpendicular to the optical axis 3 on the light reflecting side of the reflector 2, which reflects the light from the lamp 1 to be parallel to the optical axis 3. A prism 20 as an optical element is arranged on the light outgoing side of the incident-side polarization plate 4. The prism 20 has a light-incident surface inclined to the optical axis 3 and a light-outgoing surface formed perpendicular to the optical axis 3. On the light outgoing side of the prism 20, a holographic optical element 21 is provided perpendicular to the optical axis 3. On the light outgoing side of the holographic optical element 21, the LC cell 7, the outgoing-side polarization plate 8 and the projection lens 9 are arranged perpendicular to the optical axis 3 in the named order.

The prism 20 diffracts parallel lights of specific polarized light components passed the incident-side polarization plate 4 at different angles according to their wavelengths and causes the diffracted lights to leave. The prism 20 has the light-incident surface inclined to the light-outgoing surface by approximately 38.2°, as shown in Figs. 12 through 14. Accordingly, the incident angle of the light to the prism 20 becomes approximately 38.2°. The refractive index of the prism 20 is 1.962. The light of the R wavelength component (λ = 640 nm) comes out of the prism 20 at an angle of about 41.7°. The light of the G wavelength component (λ = 550 nm) comes out of the prism 20 at an angle of about 40°. The light of the B wavelength

component (λ = 460 nm) comes out of the prism 20 at an angle of about 39°.

The holographic optical element 21 diffracts light of any wavelength. The diffraction angle of the light diffracted by the holographic optical element 21 varies in accordance with the wavelength. The holographic optical element 21 causes the lights incident at their specific incident angles to enter the respective pixels of the LC cell 7 for corresponding colors. This holographic optical element 21 has unit holographic optical elements arranged in association with unit pixels each consisting of a set of three color (R, G and B) pixels of the LC cell 7. Those unit holographic optical elements have diffraction gratings formed in the same way as those of the first embodiment. In the holographic optical element 21, the pitch d_A of the diffraction grating at the point HA is set to 1.006 nm, the pitch d_B of the diffraction grating at the point HB is set to 0.848 nm and the pitch d_C of the diffraction grating at the point HC is set to 0.733 nm.

The holographic optical element 21 is arranged at an interval of approximately 10 µm with respect to the light-outgoing surface of the prism 20 and an interval of approximately 1100 µm with respect to the light-incident surface of the LC cell 7.

The operation of this LC projector will be discussed below.

In this LC projector, as shown in Fig. 11, the light from the lamp 1 is reflected by the reflector 2 to become parallel to the optical axis 3. This parallel light perpendicularly enters the incident-side polarization plate 4, which selectively passes the light of a specific polarized light component. The light of the specific polarized light component selected by the incident-side polarization plate 4 enters the prism 20 at an incident angle of 38.2°. The lights of the R, G and B wavelength components incident to the prism 20 are diffracted at

different diffraction angles by the prism 20 and respectively go out thereof at different outgoing angles, as shown in Figs. 12 to 14. The lights which have left the prism 20 enter the holographic optical element 21 at the optimal incident angles for the respective wavelength components. The lights of the individual wavelength components incident to the holographic optical element 21 are condensed to the associated pixels of the LC cell 7 for corresponding colors.

The above will be discussed specifically for each of the R, G and B wavelength components.

As shown in Fig. 12, the light of the G wavelength component incident to the prism 20 at an incident angle of 38.2° is diffracted and goes out of the prism 20 at an outgoing angle of 40°. The light having left the prism 20 enters the holographic optical element 21 at an incident angle of 40°. The light incident to the point HB of the holographic optical element 21 leaves the holographic optical element 21 substantially perpendicularly and hits the associated pixel for G of the LC cell 7. The light incident to the point HA of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for G of the LC cell 7. The light incident to the point HC of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for G of the LC cell 7.

As shown in Fig. 13, the light of the R wavelength component incident to the prism 20 at an incident angle of 38.2° is diffracted and goes out of the prism 20 at an outgoing angle of 41.7°. The light having left the prism 20 enters the holographic optical element 21 at an incident angle of 41.7°. The light incident to the point HA of the holographic optical element 21 leaves the holographic optical element 21 substantially perpendicularly and hits the associated pixel for R of the LC cell 7. The light

incident to the point HB of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for R of the LC cell 7. The light incident to the point HC of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for R of the LC cell 7.

As shown in Fig. 14, the light of the B wavelength component incident to the prism 20 at an incident angle of 38.2° is diffracted and goes out of the prism 20 at an outgoing angle of 39°. The light having left the prism 20 enters the holographic optical element 21 at an incident angle of 39°. The light incident to the point HC of the holographic optical element 21 leaves the holographic optical element 21 substantially perpendicularly and hits the associated pixel for B of the LC cell 7. The light incident to the point HB of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for B of the LC cell 7. The light incident to the point HA of the holographic optical element 21 leaves the holographic optical element 21 at a predetermined outgoing angle and hits the associated pixel for B of the LC cell 7.

According to this LC projector, as described above, the parallel light emitted from the lamp 1 and reflected by the reflector 2 is diffracted at different diffraction angles wavelength by wavelength by the first holographic optical element 5. That is, the outgoing lights of the individual wavelength components from the prism 20 enter the holographic optical element 21 at their optimal incident angles. It is therefore possible to improve the diffraction efficiency of light of each wavelength component by the holographic optical element 21 so that lights of the individual wavelengths can efficiently be diffracted by the holographic optical element 21 to be efficiently condensed on the associated pixels of the LC

cell 7 for corresponding colors. Accordingly, a clear and bright projected image can be acquired.

Fourth Embodiment

Fig. 15 is a cross-sectional view illustrating the structure of an LCD projector according to the fourth embodiment of this invention. To avoid the redundant description, like or same reference numerals are given to those components of this embodiment which are the same as the corresponding components of the third embodiment.

The incident-side polarization plate 4 is provided perpendicular to the optical axis 3 on the light reflecting side of the reflector 2, which reflects the light from the lamp 1 to be parallel to the optical axis 3. A prism lens 25 as an optical element is arranged perpendicular to the optical axis 3 on the light outgoing side of the incident-side polarization plate 4. A holographic optical element 26 is provided perpendicular to the optical axis 3 on the light outgoing side of the prism lens 25. On the light outgoing side of the holographic optical element 26, the LC cell 7, the outgoing-side polarization plate 8 and the projection lens 9 are arranged perpendicular to the optical axis 3 in the named order.

The prism lens 25 diffracts parallel lights of specific polarized light components passed the incident-side polarization plate 4 at different angles according to their wavelengths and causes the diffracted lights to leave. The light-incident surface of the prism lens 25 is a sawtooth-shaped lens surface. The light-outgoing surface of the prism lens 25 is a plane perpendicular to the optical axis 3. The prism lens 25 has microprism lenses 25a corresponding to unit pixels each consisting of three color (R, G and B) pixels of the LC cell 7. In this case, each microprism lens 25a has a light-incident lens surface inclined at an angle of 38.2° with respect to the light-outgoing plane. The refractive index of each microprism lens 25a is 1.926. The light of the R wavelength component

(λ = 640 nm) comes out of the prism lens 25 at an angle of 41.7°. The light of the G wavelength component (λ = 550 nm) comes out of the prism lens 25 at an angle of 40°. The light of the B wavelength component (λ = 460 nm) comes out of the prism lens 25 at an angle of 39°.

The holographic optical element 26 is the same as the one in the third embodiment, and condenses the light of the R wavelength component, the light of the G wavelength component and the light of the B wavelength component onto the associated pixels.

According to this LC projector, as described above, the parallel light emitted from the lamp 1 and reflected by the reflector 2 is diffracted at different diffraction angles wavelength by wavelength by the prism lens 25. That is, the outgoing lights of the individual wavelength components from the prism lens 25 enter the holographic optical element 26 at their optimal incident angles. It is therefore possible to improve the diffraction efficiency of light of each wavelength component by the holographic optical element 26 and efficiently diffract the lights of the individual wavelengths by means of the holographic optical element 26 to be efficiently condensed onto the associated pixels of the LC cell 7 for corresponding colors. This can provide a clear and bright projected image.

The microprism lenses 25a which constitute the prism lens 25 in the fourth embodiment are associated with unit pixels each consisting of three color (R, G and B) pixels of the LC cell 7. The microprism lenses 25a may however be associated with the respective pixels of the LC cell 7.

Fifth Embodiment

Fig. 16 is a cross-sectional view illustrating the structure of an LCD projector according to the fifth embodiment of this invention.

To avoid the redundant description, like or same reference numerals are given to those components of this

embodiment which are the same as the corresponding components of the first embodiment.

In this LC projector, the lamp 1 is located at the focus point of the reflector 2 which has a parabolic surface. The reflector 2 reflects light generated from the lamp 1 to produce light parallel to the optical axis 3. A holographic optical element 51 is arranged on the light reflecting side of the reflector 2 and is inclined at a predetermined angle to the optical axis 3. On the light outgoing side of the holographic optical element 51, the incident-side polarization plate 4 which selectively passes a specific polarized light component is arranged parallel to the holographic optical element 51. A flat-shaped condenser lens 50 is arranged parallel to the incident-side polarization plate 4 on the light outgoing side of this polarization plate 4. The LC cell 7 is provided parallel to the condenser lens 50 on the light outgoing side of the condenser lens 50. On the light outgoing side of the LC cell 7, the outgoing-side polarization plate 8, which selectively passes a specific polarized light component among the lights passed the LC cell 7, is arranged parallel to the LC cell 7. The projection lens 9 for projecting an image of light which has passed the outgoing-side polarization plate 8 is located on the light going side of the outgoing-side polarization plate 8.

The LC cell 7 has a liquid crystal sealed between a pair of transparent substrates on which electrodes are formed in a dot matrix form and multiple pixels are arranged in a dot matrix form. A black matrix BM for preventing light leakage is provided between the pixels on the substrate to which light is incident. As shown in Fig. 18, the LC cell 7 has unit pixels cyclically arranged, each of which consists of a set of three color (R, G, and B) pixels. The individual pixels of R, G and B are arranged in the order of B, G and R along the light splitting direction of the holographic optical element 51 (from left

to right in Fig. 18) which will be discussed later. This LC cell 7 is provided with color filters for R, G and B. The LC cell 7 may not however be provided with color filters.

The holographic optical element 51 diffracts light of any wavelength with each diffraction grating. The diffraction angle of the light diffracted by the holographic optical element 51 varies in accordance with the wavelength. As shown in Fig. 17, parallel light emitted from the lamp 1 and reflected by the reflector 2 enters the holographic optical element 51 at a predetermined incident angle. The holographic optical element 51 splits the incident light to parallel lights for individual wavelength bands. That is, the diffraction gratings of the holographic optical element 51 are formed at a uniform pitch. The holographic optical element 51 diffracts the light of the G wavelength band toward substantially the direction of the normal line and causes the light to leave accordingly. The holographic optical element 51 diffracts the light of the R wavelength band at a greater diffraction angle than that of the light of the G wavelength band and causes the light to leave accordingly. The holographic optical element 51 diffracts the light of the B wavelength band at a smaller diffraction angle than that of the light of the G wavelength band and causes the light to leave accordingly.

In Fig. 18, the light splitting direction (resolution direction) of the holographic optical element 51 is set in the left-to-right direction.

The condenser lens 50 condenses the parallel lights of individual wavelengths, split by the holographic optical element 51, on the associated pixels of the LC cell 7 for corresponding colors. The condenser lens 50 has microlenses 50a cyclically arranged which are associated with unit pixels each consisting of three color (R, G and B) pixels of the LC cell 7. As shown in Fig. 18, each

microlens 50a is formed in a hexagonal shape, which has a pixel for G of the LC cell 7 at the center and connects the centers of six adjoining pixels for R and B around the center pixel. As shown in Fig. 17, the microlenses 50a are convex lenses with the convex surfaces facing the holographic optical element 51. The microlenses 50a condenses parallel incident lights of individual wavelength bands onto the associated pixels of the LC cell 7 for corresponding colors in accordance with the wavelengths (incident angles) of the lights. Specifically, the light of the G wavelength band is condensed on the associated pixel for G of the LC cell 7, the light of the R wavelength band is condensed on the associated pixel for R of the LC cell 7, and the light of the B wavelength band is condensed on the associated pixel for B of the LC cell 7.

The operation of this LC projector will now be discussed.

As shown in Fig. 16, light from the lamp 1 is reflected by the reflector 2 to be parallel to the optical axis 3. This parallel light enters the holographic optical element 51 at a predetermined incident angle. The parallel light incident to the holographic optical element 51 is diffracted at different diffraction angles for the R, G and B wavelength bands by the holographic optical element 51 and the diffracted lights leave the holographic optical element 51 as parallel lights for the respective wavelength bands, as shown in Fig. 17. Specifically, the light of the G wavelength band is diffracted substantially in the direction of the normal line of the holographic optical element 51 and leaves the holographic optical element 51 accordingly. The light of the R wavelength band is diffracted at a greater diffraction angle than that of the light of the G wavelength band and leaves the holographic optical element 51 at a predetermined angle in the direction of the normal line of the holographic optical element 51. The light of the B wavelength band is

diffracted at a smaller diffraction angle than that of the light of the G wavelength band and leaves the holographic optical element 51 at a predetermined angle in the opposite direction to the outgoing direction of the light of the R wavelength band with respect to the normal line of the holographic optical element 51.

The outgoing light from the holographic optical element 51 enters the incident-side polarization plate 4, which selectively passes specific polarized light components. The lights passed the incident-side polarization plate 4 enter the respective microlenses 50a of the condenser lens 50 at incident angles which differ wavelength by wavelength. The lights incident to the microlenses 50a at the different incident angles are condensed on the associated pixels of the LC cell 7 for corresponding colors by the microlenses 50a as shown in Fig. 17. Specifically, the light of the G wavelength band which has substantially perpendicularly entered the associated microlens 50a is condensed on the associated pixel for G of the LC cell 7. The light of the R wavelength band which has entered the associated microlens 50a at a predetermined angle is condensed on the associated pixel for R of the LC cell 7. The light of the B wavelength band which has entered the associated microlens 50a at a predetermined angle in the opposite direction to the direction of the light of the R wavelength band is condensed on the associated pixel for B of the LC cell 7.

Specific polarized light components of the light passed through the LC cell 7 are selectively passed by the outgoing-side polarization plate 8. The lights passed this outgoing-side polarization plate 8 are projected as an image by the projection lens 9.

According to this LC projector, as described above, parallel light emitted from the lamp 1 and reflected by the reflector 2 is diffracted at different diffraction angles for the respective R, G and B wavelength bands by the

holographic optical element 51. Parallel lights with different incident angles for the respective R, G and B wavelength bands leave the holographic optical element 51. It is therefore possible to split the light from the lamp 1 to light components of individual wavelength bands with fewer parts. This feature simplifies the structure of the LC projector.

Further, the microlenses 50a of the condenser lens 50 condense the respective lights, split by the holographic optical element 51, on the associated pixels of the LC cell 7 in accordance with the wavelength bands. This prevents lights of complementary color components from being absorbed by color filters or prevents the light from the lamp 1 from being shielded by the black matrix BM. This LC projector can therefore prevent light loss. It is thus possible to improve the efficiency of using the light from the lamp 1 and acquire a bright color image and a bright projected image.

Modifications

The holographic optical elements 5, 15 and 51 used in the first, second and fifth embodiments diffract light of any wavelength band with each diffraction grating so that light is diffracted at different diffraction angles wavelength by wavelength. That is, although each of the holographic optical elements used in the first, second and fifth embodiments has a single element structure, the structures of those holographic optical elements are not limited to this type. For instance, a three-layer structure in which three types of holographic optical elements capable of selectively passing lights of the respective R, G and B wavelengths may be used.

The holographic optical elements in the first, second and fifth embodiments and the prisms in the second and fourth embodiments are used as means for splitting parallel light from the lamp. According to this invention, however, any optical means which splits incident light wavelength by

wavelength and emits the split light components wavelength by wavelength may be used in placed of the holographic optical elements and prisms.

The incident-side polarization plate is arranged on the light incident side of the optical means (the holographic optical elements 5 and 15 and the prisms 20 and 25) in the first to fourth embodiments, whereas the incident-side polarization plate is arranged on the light outgoing side of the optical means in the fifth embodiment. The incident-side polarization plate may however be arranged on either side.

The holographic optical elements in the first to fourth embodiments and the microlenses in the fifth embodiment are used as means for condensing lights incident at different angles for the respective wavelength bands onto predetermined and associated pixels. According to this invention, however, any optical means which condenses lights incident at different angles for the respective wavelength bands on predetermined and associated pixels may be used instead of the mentioned holographic optical elements and microlenses.

Although each microlens has a hexagonal shape in the fifth embodiment, the structure of the microlens is not limited to this type. For example, as shown in Fig. 19, each of unit pixels may have three pixels for R, G and B arranged linearly and each microlens 50b may be formed in a rectangular shape in association with this unit pixel. The condenser lens is formed by cyclically arranging those microlenses 50b.

Although the foregoing description of the first to fifth embodiments has been given of the case where this invention is adapted to an LC projector, this invention is not limited to this particular application. This invention may be adapted to a variety of LCD apparatuses which allow an observer to directly view an image displayed on the LC cell 7.

The LCD apparatuses according to the first to fifth embodiments are to be considered as some of adaptable forms of this invention. This invention can be adapted to any LCD apparatus which uses combined two optical means. How to combine those two optical means and the characteristics of those two optical means may be selected to provide the desired results through experiments.

CLAIMS

1. A liquid crystal display apparatus comprising:

a light source (1, 2) for supplying a substantially parallel light flux;

a liquid crystal device (7) having multiple pixels;

a first holographic optical element (5, 15) for splitting said substantially parallel light flux from said light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting said split light fluxes in different directions respectively; and

a second holographic optical element (6, 16) for guiding said plurality of light fluxes of different wavelength bands emitted from said first holographic optical element (5, 15) to predetermined pixels of said liquid crystal device (7) wavelength band by wavelength band.

2. The liquid crystal display apparatus according to claim 1, wherein said first holographic optical element (5, 15) splits a substantially parallel light flux from said light source (1, 2) into a plurality of parallel light fluxes of different wavelength bands and emitting said split parallel light fluxes in different directions respectively.

3. The liquid crystal display apparatus according to claim 1, wherein each of incident angles of said plurality of light fluxes of different wavelength bands incident to said second holographic optical element (6, 16) falls within a predetermined range including an incident angle which maximizes a diffraction efficiency of said second holographic optical element (6, 16) for each of said wavelength bands of said light fluxes.

4. The liquid crystal display apparatus according to claim 1, wherein light from said light source (1, 2) obliquely hits said first holographic optical element (5).

5. The liquid crystal display apparatus according to claim 4, further comprising a polarization plate (4)

provided between said light source (1, 2) and said liquid crystal device (7), whereby a light flux from said light source (1, 2) perpendicularly enters said polarization plate (4).

6. The liquid crystal display apparatus according to claim 1, wherein said first holographic optical element (5, 15) and said second holographic optical element (6, 16) are respectively provided on both sides of a transparent plate (10).

7. The liquid crystal display apparatus according to claim 1, wherein said first holographic optical element (5, 15) and said second holographic optical element (6, 16) are stacked on one side of a transparent plate (10).

8. The liquid crystal display apparatus according to claim 1, wherein a diffraction angle when light from said light source (1, 2) is diffracted by said first holographic optical element (5, 15) becomes larger as a wavelength of said light becomes longer.

9. A liquid crystal display apparatus comprising:

a light source (1, 2) for supplying a substantially parallel light flux;

a liquid crystal device (7) having multiple pixels;

a prism (20, 25) for splitting said substantially parallel light flux from said light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting said split light fluxes in different directions respectively; and

a holographic optical element (21, 26) for guiding said plurality of light fluxes of different wavelength bands emitted from said prism (20, 25) to predetermined pixels of said liquid crystal device (7) wavelength band by wavelength band.

10. The liquid crystal display apparatus according to claim 9, wherein said prism (20, 25) splits a substantially parallel light flux from said light source (1, 2) into a plurality of parallel light fluxes of different wavelength

bands and emitting said split parallel light fluxes in different directions respectively.

11. The liquid crystal display apparatus according to claim 9, wherein said prism (25) is an assembly of a plurality of microprisms (25a).

12. The liquid crystal display apparatus according to claim 9, wherein said prism (20, 25) splits a substantially parallel light flux from said light source (1, 2) into a plurality of substantially parallel light fluxes of different wavelength bands and emitting said split parallel light fluxes to different directions respectively.

13. The liquid crystal display apparatus according to claim 9, wherein each of incident angles of said plurality of light fluxes of different wavelength bands incident to said holographic optical element (21, 26) from said prism (20, 25) falls within a predetermined range including an incident angle which maximizes a diffraction efficiency of said holographic optical element (21, 26) for each of said wavelength bands of said light fluxes.

14. A liquid crystal display apparatus comprising:

a light source (1, 2) for supplying a substantially parallel light flux;

a liquid crystal device (7) having multiple pixels;

a holographic optical element (51) for splitting said substantially parallel light flux from said light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting said split light fluxes in different directions respectively; and

a lens (50) for guiding said plurality of light fluxes of different wavelength bands emitted from said holographic optical element (51) to predetermined pixels of said liquid crystal device (7) wavelength band by wavelength band.

15. The liquid crystal display apparatus according to claim 14, wherein said holographic optical element (51) splits a substantially parallel light flux from said light source (1, 2) into a plurality of parallel light fluxes of

different wavelength bands and emitting said split parallel light fluxes in different directions respectively.

16. The liquid crystal display apparatus according to claim 14, wherein said lens (50) is comprised of a plurality of microlenses (50a) respectively corresponding to a plurality of pixels of said liquid crystal device (7).

17. The liquid crystal display apparatus according to claim 16, wherein said plurality of light fluxes of different wavelength bands respectively enter said plurality of microlenses (50a).

18. The liquid crystal display apparatus according to claim 14, wherein a plurality of light fluxes of different wavelength bands emitted from one point of said holographic optical element (51) enter respective pixels of said liquid crystal device (7) wavelength band by wavelength band.

19. A liquid crystal display apparatus comprising:

a light source (1, 2) for supplying a substantially parallel light flux;

a liquid crystal device (7) having multiple pixels;

first optical means (5, 15; 20, 25; 51) for splitting said substantially parallel light flux from said light source (1, 2) into a plurality of light fluxes of different wavelength bands and emitting said split light fluxes in different directions respectively; and

second optical means (6, 16; 21, 26; 50) for guiding said plurality of light fluxes of different wavelength bands emitted from said first optical means (5, 15; 20, 25; 51) to predetermined pixels of said liquid crystal device (7) wavelength band by wavelength band.

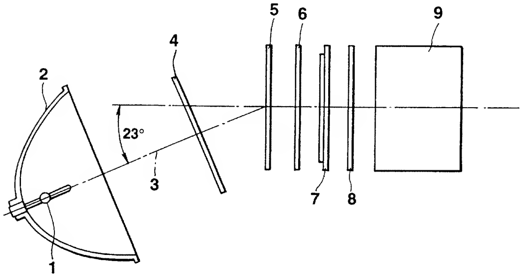


FIG.1

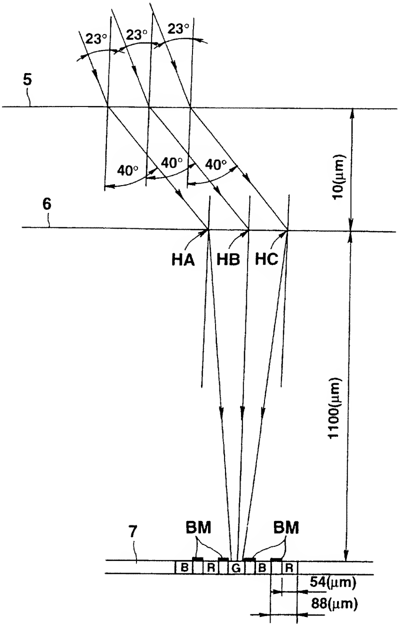


FIG.2

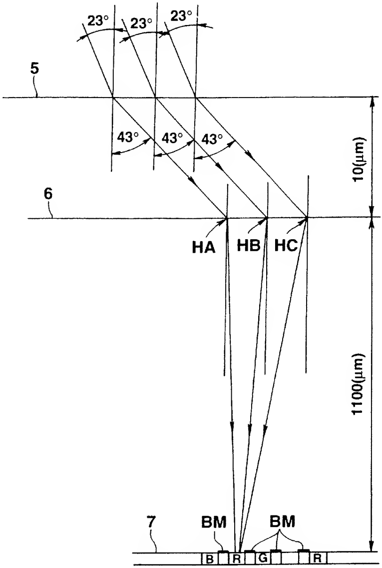


FIG.3

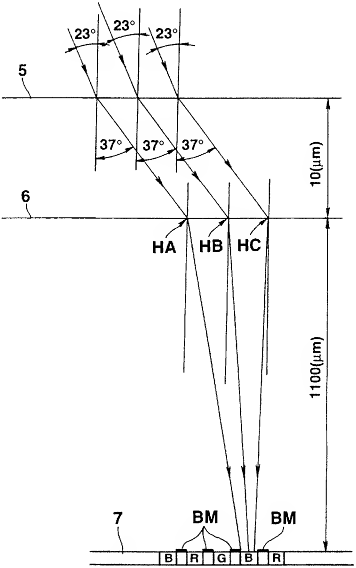


FIG.4

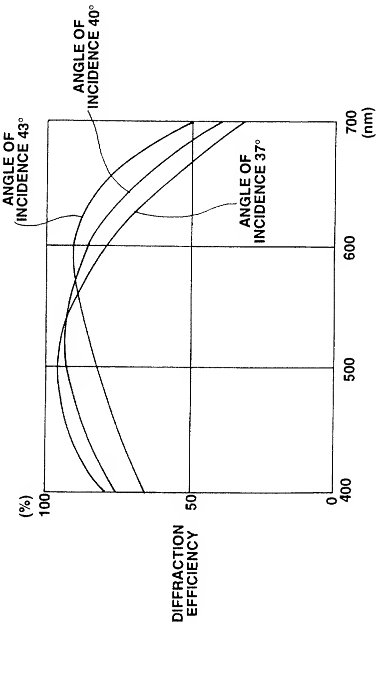

ANGLE OF INCIDENCE 43°
ANGLE OF INCIDENCE 40°
ANGLE OF INCIDENCE 37°
DIFFRACTION EFFICIENCY
(%)
100
50
0
400
500
600
700
(nm)

FIG.5

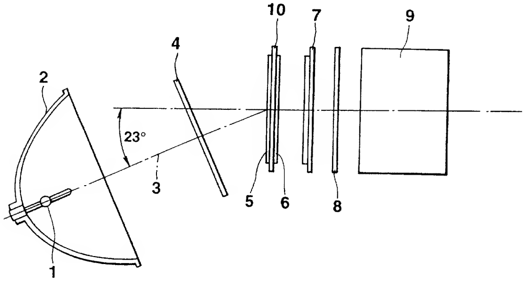


FIG.6

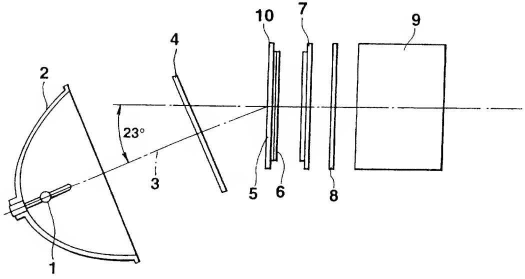


FIG.7

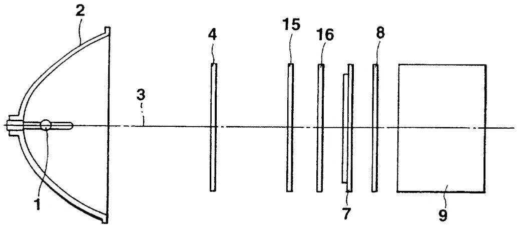


FIG.8

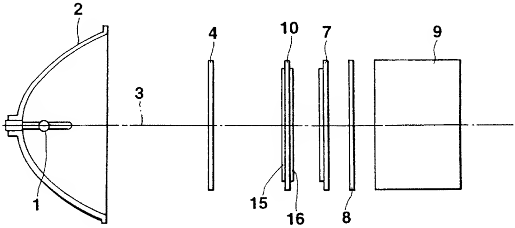


FIG.9

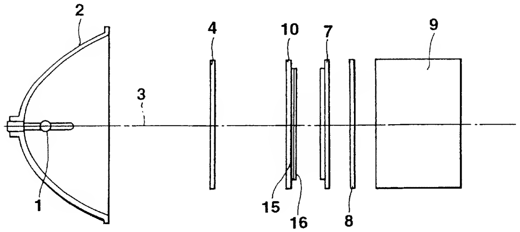


FIG.10

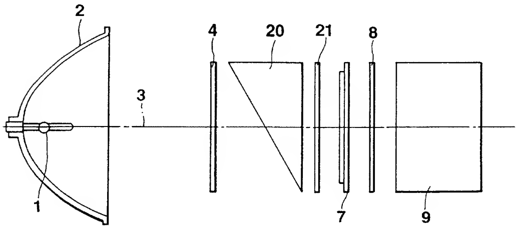


FIG.11

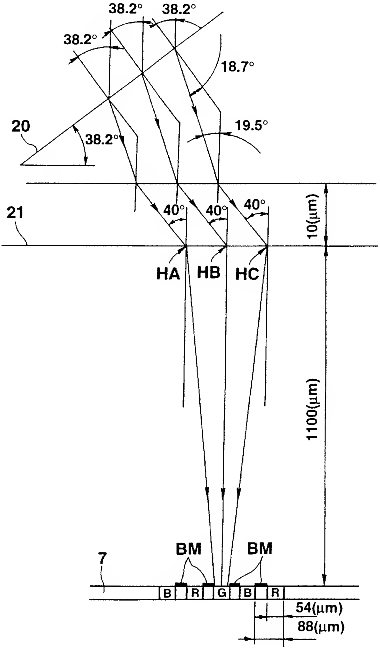

38.2°
38.2°
38.2°
18.7°
20
38.2°
19.5°
21
40°
40°
40°
10(μm)
HA
HB
HC
1100(μm)
7
BM
BM
B
R
G
B
R
54(μm)
88(μm)

FIG.12

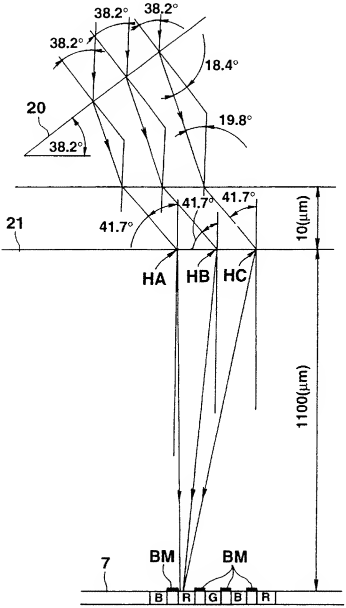
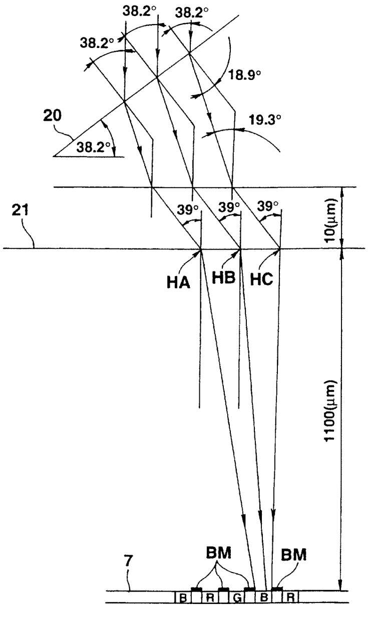

38.2°
38.2°
38.2°
18.4°
20
19.8°
38.2°
41.7°
41.7°
21
41.7°
10(μm)
HA
HB
HC
1100(μm)
7
BM
BM
B
R
G
B
R

FIG.13


38.2°
38.2°
38.2°
18.9°
20
19.3°
38.2°
21
39°
39°
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10(μm)
HA
HB
HC
1100(μm)
BM
BM
7
B
R
G
B
R

FIG.14

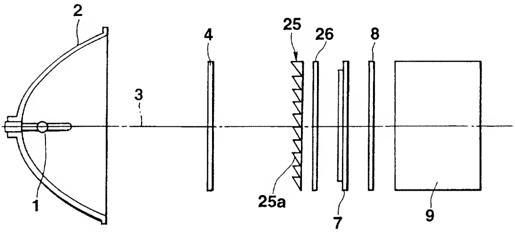

FIG.15

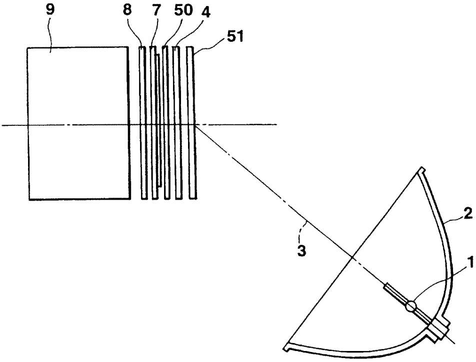

FIG.16

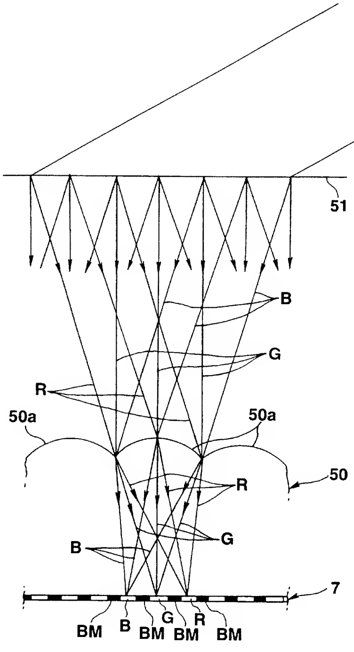

FIG.17

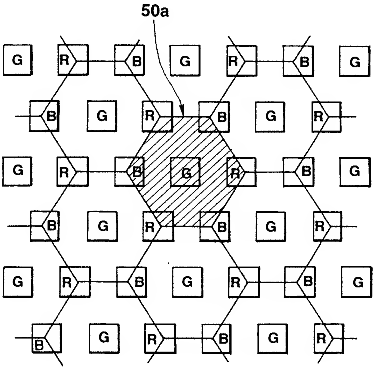

FIG.18

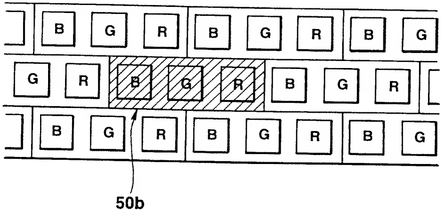

FIG.19

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 96/02837

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02F1/1335 G02B5/32 H04N9/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02F G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 06 222 361 A (DAI NIPPON) 12 August 1994	1-8,19
Y	see figure 3	9-13
P,X	& US 5 506 701 A (ICHIKAWA) 9 April 1996	1-8, 14-19
	see column 3, line 05 - column 6, line 56; figure 3	

Y	GB 2 152 724 A (CITIZEN WATCH) 7 August 1985	9-13
	see page 2, line 17 - line 81; figure 3	

X	PATENT ABSTRACTS OF JAPAN vol. 18, no. 7 (P-1670) & JP 05 249318 A (SHIMADZU) see abstract	14-19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
4 December 1996	11. 12. 96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Diot, P

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 00-00) & JP 07 092327 A (DAINIPPON PRINTING), 7 April 1995, see abstract -----	19

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Interr al Application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP-A-6222361	12-08-94	US-A- 5506701	09-04-96
GB-A-2152724	07-08-85	JP-A- 60146590	02-08-85
		US-A- 4686519	11-08-87